GUN LAUNCH DYNAMICS OF THE
NAVY 5-INCH GUIDED PROJECTILE

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ABSTRACT

The design and qualification of the Navy 5-inch guided projectile components and structure were accomplished by a combination of analytical and experimental techniques. Gun launch accelerations approach 8000 g and produce the peak structural loads. The rapid pressure decay on the projectile base at muzzle exit drives the shock loading of internal components. An analytical model was used to calculate structural loads and to define the shock environment for components. The structure and components were qualified by testing them in canisters fired from 8-inch guns, and also in the laboratory using shock machines and a pendulum impact facility.

The Navy 5" Guided Projectile (GP) is a gun launched, fin stabilized, terminally guided projectile. It uses interchangeable semiactive laser and infrared guidance units. The infrared system is a point defense weapon capable of intercepting high speed air targets. The semiactive laser system is designed to attack illuminated moving and stationary surface targets.

The GP, shown in Figure 1, consists of a guidance head, control section, warhead, motor, and stabilizing fins. An obturator is located at the aft end of the motor; it decouples the GP from the spin induced by the rifling of the gun, and also prevents high pressure gases from propagating forward. The rocket motor is a low thrust propulsion unit, used to obtain increased range for the GP. Both guidance systems achieve required terminal accuracy by canard control surfaces and a gyro-stabilized seeker.

The pressures acting on the base of the GP during gun launch are shown in Figure 2. The peak gun launch pressure is 43,000 psi, which results in a rigid body acceleration of approximately 8000 g. At muzzle exit the pressure is nominally 7500 psi. For a worn gun, the muzzle exit pressure can be as high as 9500 psi. In both cases, the rate of decay of the base pressure has been determined to be very rapid, falling exponentially to 100 psi in approximately 500 microseconds. As will be discussed later, this rapid pressure decay at muzzle exit is the driver for the set forward (tension) loads of the GP primary structure; it also is the principal contributor to the shock loading of internal components.

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Design requirements for the GP primary structure have been determined from the following conditions:

- set back
- balloting
- angular acceleration
- set forward

The set back (compression) loads are directly related to the peak base pressure. They are of relatively long duration when compared to the period of the GP structural modes. Consequently, they can be considered to be the equivalent of static loads.

The balloting loads are lateral loads that result from lateral impacting of the GP structure against the bore of the gun during launch. These loads are difficult to define accurately but they have been found to be small when compared to other gun loads.

The angular acceleration which results from the rifling in the bore is 60,000 radians/sec^2. Again, this condition produces relatively small loads. However, it is important in defining right hand or left hand requirements for threaded joints and preload nuts in order to prevent loss of preload during gun launch.

The maximum set forward loads occur at muzzle exit and their magnitude is strongly influenced by the rate of decay of the base pressure. As noted earlier the rate of decay is very rapid and results in strong excitation of the GP structural modes. The set forward design loads were calculated by means of a dynamic response analysis of the GP to the gun launch pressure time history. The model used in the analysis included structural modes up to 10 KHz and damping 2 percent of critical.
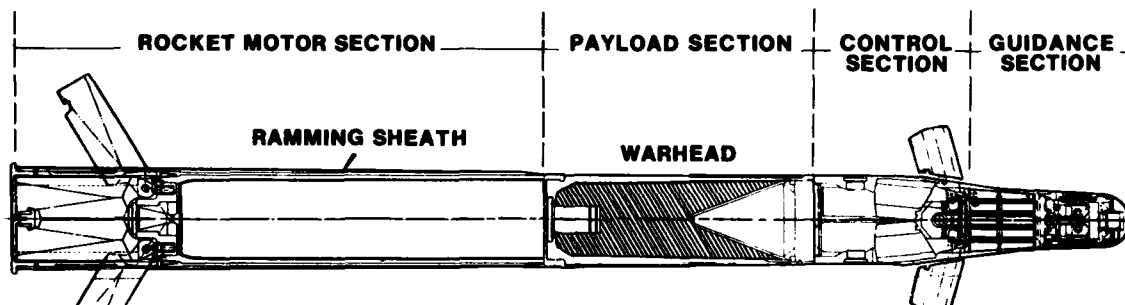
The same model was used to calculate the input shock environment for internally mounted components. A typical acceleration response of the GP structure to the gun launch pressure pulse is shown in Figure 3. The oscillatory response shown at muzzle exit is composed primarily of the response of the first two longitudinal modes of the GP. These modes have frequencies of 1350 Hz and 2200 Hz. The higher modes contribute very little to the overall dynamic response.

The shock spectra calculated from the acceleration response time history are shown in Figure 4. Two types of spectra are shown. The maxi-max spectra, which are almost always the maximum positive spectra, represent set back loadings. The maximum negative spectra shown represent set forward loadings. These spectra are useful for the design of components which are more critical for set forward loading than they are for set back loading. The negative spectra are also useful in defining the preload required for component assemblies to prevent unloading which would result in impacting of the component elements.

Two test methods have been developed to qualify components for the gun launch shock environment. The first method involves testing on a standard shock machine using a shock amplifier system. A lightweight and a heavy weight amplifier have been used. The lightweight amplifier is shown in Figure 5. These amplifiers have the capability of producing half sine pulses ranging from 5 Kg and 400 microseconds duration to 30 Kg and 120 microseconds duration.

The second test method involves testing in a full up GP structure which is impacted at the rear by a 34 pound hammer swung on the end of a 14 foot pendulum (Figure 6). This test method is particularly attractive since the GP structure is able to provide a shock transient which has the correct frequency content. Another advantage of the pendulum shock test is that the effect of structural joints opening and impacting on closing, as would occur at muzzle exit, are included in the test. This test method also qualifies the GP primary structure for the design set forward loads when the peak set forward g loadings are achieved. Pendulum shock test results have also been used to verify the accuracy of the analytical model.

Qualification of structure and components for set back loading is accomplished by installing these systems in canisters which are fired out of 8 inch guns and parachute recovered. Smaller structures and components are being qualified by testing in a small, high g centrifuge normally used to test microelectronic parts.

| ROCKET MOTOR SECTION | PAYLOAD SECTION | CONTROL SECTION | GUIDANCE SECTION |

RAMMING SHEATH   WARHEAD

Length: 60.97 Inches
Weight: 104.7 Pounds
Guidance: Proportional Navigation
Seeker: Semiactive Laser
Controls: Cold Gas Pneumatic

Figure 1. Navy 5-Inch Guided Projectile

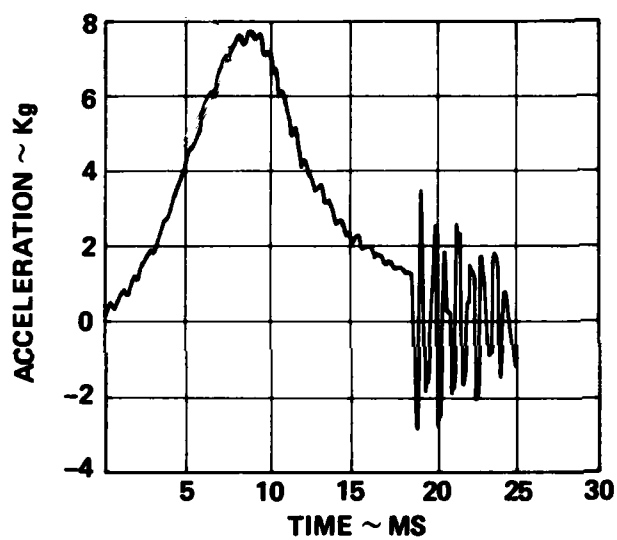Figure 2. 5-Inch GP Base Pressure

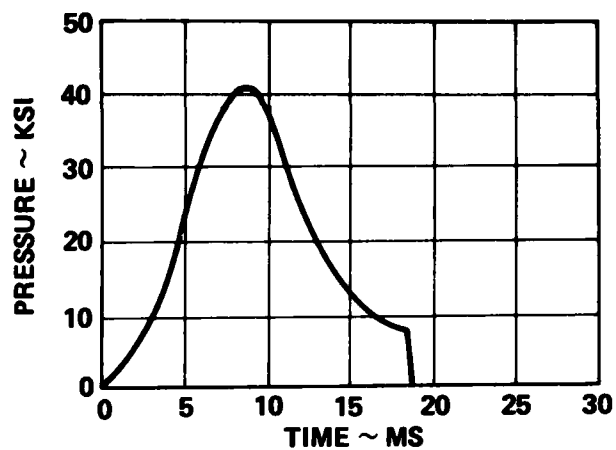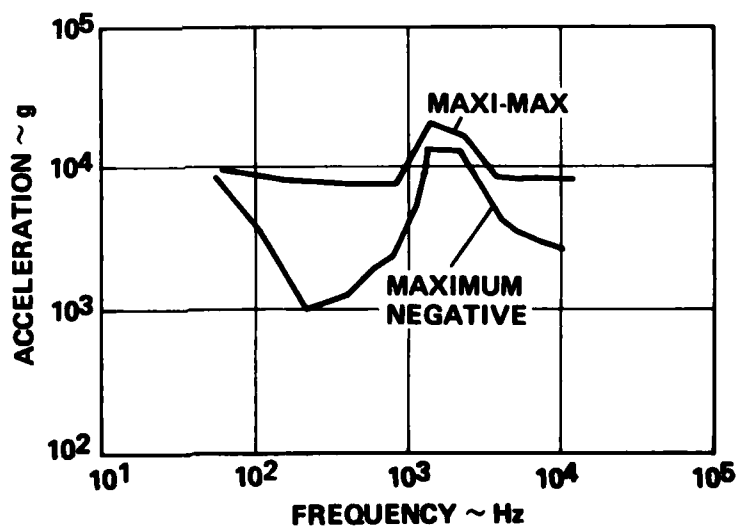
Figure 3. GP Response to
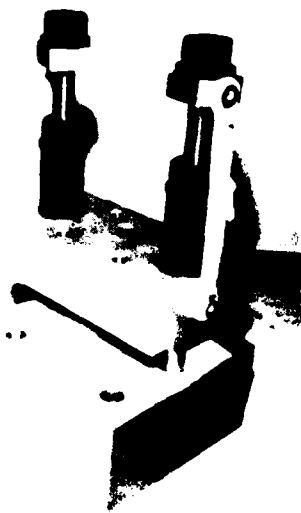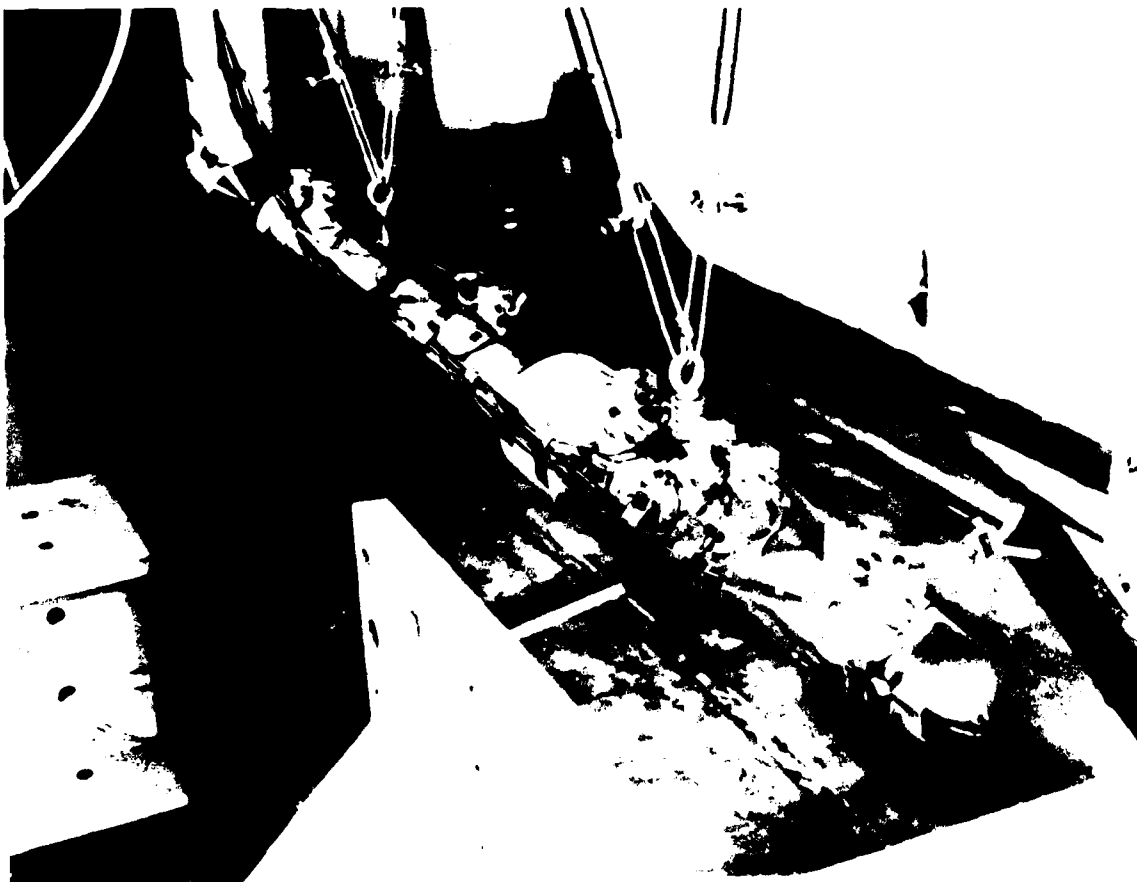Gun Launch Pressure Pulse

Figure 4. Shock Spectra

Figure 5. Lightweight Amplifier

Figure 6. Pendulum Impact Test